

**UNITED STATES PATENT APPLICATION**

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**CATHODE FLUID CONTROLLING ASSEMBLY FOR USE IN A DIRECT  
OXIDATION FUEL CELL SYSTEM**

## **CATHODE FLUID CONTROLLING ASSEMBLY FOR USE IN A DIRECT OXIDATION FUEL CELL SYSTEM**

### **BACKGROUND OF THE INVENTION**

#### ***Field of the Invention***

5           This invention relates generally to direct oxidation fuel cells, and more particularly, to controlling fluids on the cathode side of a fuel cell system.

#### ***Background Information***

          Fuel cells are devices in which an electrochemical reaction involving a fuel molecule is used to generate electricity. A variety of compounds may be suited for use as  
10   a fuel depending upon the specific nature of the cell. Organic compounds, such as methanol or natural gas, are attractive fuel choices due to their high specific energy.

          Fuel cell systems may be divided into "reformer-based" systems (i.e., those in which the fuel is processed in some fashion to extract hydrogen from the fuel before it is introduced into the fuel cell system) or "direct oxidation" systems in which the fuel is fed  
15   directly into the cell without the need for separate internal or external processing. Many currently developed fuel cells are reformer-based systems. However, because fuel processing is complex and generally requires components which occupy significant volume, reformer based systems are presently limited to comparatively large, high power applications.

20           Direct oxidation fuel cell systems may be better suited for a number of applications in smaller mobile devices (e.g., mobile phones, handheld and laptop computers), as well as in some larger scale applications. In many direct oxidation fuel cells, a carbonaceous liquid fuel (typically methanol or an aqueous methanol solution) is introduced to the anode face of a membrane electrode assembly (MEA).

One example of a direct oxidation fuel cell system is a direct methanol fuel cell system, or DMFC system. In a DMFC system, methanol or a mixture comprised of methanol and water is used as fuel (the "fuel mixture"), and oxygen, preferably from ambient air, is used as the oxidizing agent. The fundamental reactions are the anodic  
5 oxidation of the fuel mixture into CO<sub>2</sub>, protons, and electrons; and the cathodic combination of protons, electrons and oxygen into water.

Typical DMFC systems include a fuel source, fluid and effluent management sub-systems, and air management sub-systems, in addition to the direct methanol fuel cell itself ("fuel cell"). The fuel cell typically consists of a housing, hardware for current  
10 collection and fuel and air distribution, and a membrane electrode assembly ("MEA"), which are all typically disposed within the housing.

The electricity generating reactions and the current collection in a direct oxidation fuel cell system take place within and on the MEA. In the fuel oxidation process at the anode, the products are protons, electrons and carbon dioxide. Protons (originating from  
15 fuel and water molecules involved in the anodic reaction) migrate through the catalyzed membrane electrolyte, which is impermeable to the electrons. The electrons travel through an external circuit, which includes the load, and are united with the protons and oxygen molecules in the cathodic reaction, thus providing electrical power from the fuel cell and water product at the cathode of the fuel cell.

20 A typical MEA includes a centrally disposed protonically-conductive, electronically non-conductive membrane ("PCM", sometimes also referred to herein as "the catalyzed membrane"). One example of a commercially available PCM is Nafion ® a registered trademark of E.I. Dupont de Nemours and Company, a cation exchange membrane based on polyperfluorosulfonic acid, in a variety of thicknesses and equivalent  
25 weights. The PCM is typically coated on each face with an electrocatalyst such as platinum, or platinum/ruthenium mixtures or alloy particles. The PCM should be adequately hydrated for optimal performance. On either face of the catalyst coated PCM, the electrode assembly typically includes a diffusion layer. The diffusion layer on the anode side is employed to evenly distribute the liquid fuel mixture across the catalyzed  
30 anode face of the PCM, while allowing the gaseous product of the reaction, typically carbon dioxide, to move away from the anode face of the PCM. In the case of the

cathode side, a wet-proofed diffusion layer is used to allow a sufficient supply of oxygen by minimizing or eliminating the build-up of liquid, typically water, on the cathode aspect of the PCM. Each of the anode and cathode diffusion layers also assists in the collection and conduction of electric current from the catalyzed PCM.

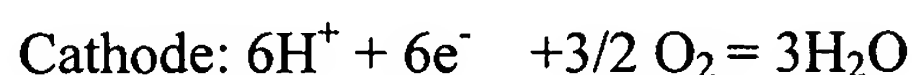
5 Direct oxidation fuel cell systems for portable electronic devices should be as small as possible at the power output required. The power output is governed by the rate of the reactions that occur at the anode and the cathode of the fuel cell. More specifically, the anode process in direct methanol fuel cells based on acidic electrolytes, including polyperfluorosulfonic acid and similar polymer electrolytes, involves a reaction  
10 of one molecule of methanol with one molecule of water. In this process, the oxygen atom in the water molecule is electrochemically activated to complete the oxidation of methanol to a final CO<sub>2</sub> product in a six-electron process.

More specifically, direct methanol fuel cell system produces electricity without combustion by oxidizing a carbonaceous fuel (typically methanol in an aqueous solution)  
15 on a catalyzed protonically conductive membrane.

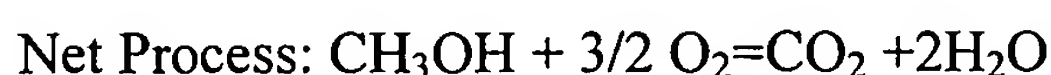
The electrochemical reaction equations are as follows:



Equation 1



20 Equation 2



Equation 3

Generation of electricity continues until one of the fluids is not available. DMFCs are typically described as “on” i.e. providing electrical current by reacting the  
25 fuel and oxygen to generate water, or “off” i.e. at least one fluid is not available because all fuel has been consumed, or air (or other source of oxygen) is prevented from reaching the cathode face of the PCM. Those skilled in the art will recognize that fuel can be delivered to the anode aspect of the MEA as a liquid, or in vaporous form.

Thus, the efficiency of a direct methanol fuel cell system is dependent in part on the amount of fluids and products that are present in the active catalyzed membrane areas. For example, it is desirable to regulate the amount of fuel that is delivered depending on the operating point of the fuel cell system. It may be further desirable to interrupt the delivery of fuel to the anode aspect of the MEA in order to shut the fuel cell system down. Commonly assigned United States Patent Application for A VAPOR FEED FUEL CELL SYSTEM WITH CONTROLLABLE FUEL DELIVERY, Serial No. 10/413, 986 by Hirsch et al. filed on April 15, 2003, describes a fuel cell system which includes an adjustable fuel delivery regulation assembly that causes fuel to be controlled as it flows generally toward the anode aspect of the catalyzed membrane electrolyte.

Controlling the reaction on the cathode side is also desirable. As noted, the reaction of the cathode side is given by Equation (2) above. As can be seen from the Equation 2, oxygen is necessary for the reaction and water is created in the reaction on the cathode side as the cell operates. Thus, both of these fluids should be adequately controlled in order to reach or maintain a desired optimal fuel cell operating condition. This is true even when the cell is in a powered down state. For example, particularly in a vapor fuel fed cell, there is a high tendency for catalyzed membrane to dry out when the fuel cell is shut down. This is because the vapor feed is not aqueous, instead it is substantially pure fuel, such that there is essentially no excess water on the anode side to keep the membrane hydrated. This is undesirable as the membrane should remain well-hydrated for optimal performance. In addition, when the fuel cell is not in operation, the membrane (and the adjacent electrocatalyst electrodes together forming the MEA) of a micro fuel cell system may become dehydrated due, at least in part, to the lack of water generation at the cathode, for example, when the fuel cell system is shut off. This is undesirable in many situations; for example, where a fuel cell system is used in a hybrid power source that contains the fuel cell and a battery. If the battery discharges, or during re-charge, the fuel cell operates to power the device. However, while the battery (or other power source) is providing power to the device, the fuel cell may be a shut down, and as such the water-generating cathodic reactions will not occur. During this time period, cell dehydration can occur, and if it does, the fuel cell may then not be able to provide sufficient power when needed, but will require that the membrane electrolyte

become rehydrated to allow for the proper reactions to occur. As such it is desirable to maintain proper hydration of the membrane electrolyte to facilitate the rapid generation of electricity, in order to avoid the time lag associated with rehydrating the membrane electrolyte and/or the fuel cell system.

5           As noted, in addition to maintaining adequate control of the water in the cathode chamber, the operation of the fuel cell can also be affected by controlling the amount of oxygen that reaches the cathode aspect of the catalyzed membrane. This can occur by controlling the amount of oxygen which is available to the cathode, or by controlling the amount of ambient air which can be introduced to the cathode aspect of the membrane  
10       electrode assembly in an ambient air-breathing cell.

          Accordingly, there remains a need for a fuel cell system and associated method that promotes humidity at the cathode aspect of the catalyzed membrane, particularly when the fuel cell system is not operating which includes an initial post-factory time frame. There remains a further need for a system and method that allows an easier  
15       startup, especially with highly concentrated methanol solutions that do not carry enough water to rehydrate the membrane on the anode side. There is a further need for a fuel cell system and associated method for controlling the flux of fluids, and specifically water and oxygen, at the cathode aspect of a DMFC and DMFC system.

          It is thus an object of the invention to provide a fluid controlling assembly for use  
20       on the cathode side of a fuel cell with a direct oxidation fuel system.

## **SUMMARY OF THE INVENTION**

          The limitations of prior techniques are overcome by the present invention, which provides a unique direct oxidation fuel cell system that includes a fluid controlling assembly on the cathode side of the fuel cell. In accordance with the present invention,  
25       an adjustable fluid controlling assembly is disposed at or near the cathode chamber which performs one or more alternative functions. More specifically, the cathode fluid controlling assembly can be used to regulate the amount of oxygen that enters the cathode chamber, which in turn, regulates the cathode half reaction. In addition, the cathode controlling assembly may in addition, or alternatively, be used to regulate the rate at



which oxygen is introduced to the cathode aspect of the MEA, and the rate at which water can escape from the cathode aspect of the MEA. By doing so, it is possible to regulate the amount of water that is present in the cathode chamber in proximity to the catalyzed membrane, and in particular to maintain humidity in the cathode chamber of the fuel cell so that the PCM is well-hydrated and ready for operation. The adjustable fluid controlling assembly of the present invention can be embodied in a variety of alternative materials and constructions. In accordance with one aspect of the invention, a gas and/or liquid impermeable film or membrane (or several sheets of such material) can be disposed between the cathode aspect of the MEA and the ambient environment to maintain humidity in the cathode chamber, while limiting or substantially preventing any air from entering the cathode when the fuel cell is shut down. Alternatively, the film can be a gas permeable membrane that permits enough oxygen flux to support fuel cell operation while still limiting water flux such that the humidity in the cathode chamber is retained. The film can be combined with other structures or materials, so that it is adjustable and can be used to control water and/or oxygen travelling in and out of the cathode chamber.

More specifically, in accordance with one embodiment of the invention for use typically with an air breathing DMFC, a gas impermeable material is stretched across a hinged metal frame which can be opened and closed over the air breathing face of a direct oxidation fuel cell to close off the fuel cell such that water is maintained within the cathode chamber when the fuel cell is not in operation, in order to maintain the hydration of the catalyzed membrane even when water is not being generated at the cathode.

More specifically, windows located in the external faceplate allow for ambient air to enter the fuel cell. The metal frame with a plurality of shutters attached on hinges is located adjacent to the air breathing windows. In a closed position, the shutters maintain water in the cathode chamber. When in an open position, air can enter the fuel cell and water vapor can escape. Intermediate positions control the amount of water and air that may flow into and out of the cathode chamber and this is typically in proportion to the size of the openings provided. Alternatively, a gas permeable material can be selected to

regulate the humidity in the cathode chamber, while allowing sufficient oxygen access to the cathode aspect of the MEA.

In accordance with another embodiment of the invention, a structure that includes two correspondingly perforated shutter components is provided. These structures can be formed as slidable shutters that have perforations that are correspondingly located on each shutter component. When the components are positioned relative to one another in a first position, the perforations are aligned forming apertures. When the components are positioned relative to one another in a second position, there are no apertures and the shutter is closed to maintain most of the water within the cathode chamber.

Alternatively, when the shutter is partially opened the apertures allow water vapor within the cathode to escape in order to avoid cathode flooding, and to allow oxygen flow into the cathode chamber.

In yet another embodiment of the invention the fluid controlling cathode shutter is a component that is fabricated from materials that react to certain conditions and change permeability by either expanding or contracting (thus closing the fluid controlling assembly), then in the reverse state, react to open the fluid controlling assembly under a different set of conditions. One of the operating characteristics that may be used in accordance with the invention to regulate or actuate the change in state of a component comprised of a reactive material (in order to open or close the control assembly) includes current passing through the component. It is noted that a material can be selected that expands or contracts based upon its own internal resistance directly, by using selected materials, such as piezoelectric materials or polyelectrolyte gel, or indirectly by using a material whose dimensions change as a current passes through it, due to the heat generated by the resistance to the current. It is further possible that the component could also serve a current conductor.

Another condition for the actuation of the reactive material component is water absorption in that when the component absorbs water it expands to retain the water within the fuel cell. Then, when the component is compressed, it releases water, which is thereafter allowed to escape the cathode chamber. Alternatively, such a component can



be used as a water supply to reinstate the humidification in the cathode chamber when it is compressed to release the water.

Another type of material is one which, when compressed, becomes less permeable to water, or a material which, when expanded, becomes less permeable to water, thus  
5 essentially preventing oxygen from being introduced to the cathode chamber, and preventing water from escaping the cathode chamber.

The various embodiments of the invention can be actuated in a number of different ways. For example, with respect to the mechanical embodiments, a spring closure mechanism that automatically closes the shutter assembly can be employed to  
10 trigger a closure to retain the necessary humidity under desired conditions. Several triggers can be used to activate the spring. For example, automatic actuation can be provided which responds to an operating characteristic of the fuel cell system such that either the spring closure or the shutters themselves are automatically engaged to open or close, depending upon on the change in the operating condition, or at a point when an  
15 operating characteristic reaches a predetermined threshold. For example, a threshold fuel cell power output can be used such that, when the fuel cell system power output drops below a critical level (indicating a power shut down), the spring will be activated, closing the shutter and maintaining humidity during the power-down state. Alternatively, power output and internal resistance, either alone or independently, may be used to actuate the  
20 fluid controlling assembly

Furthermore, several implementations of resetting mechanisms can be employed in accordance with the present invention. For example, a manual reset lever or switch that returns the spring to its untripped position may also simultaneously open the cathode fluid controlling assembly to facilitate oxygen access and the elimination of water from  
25 the cathode aspect of the fuel cell.

For the reactive material embodiments, similar triggers can be used to active the materials to change states to close the cathode chamber, or as noted above to allow the fuel cell system to return to normal operating conditions.

## BRIEF DESCRIPTION OF THE DRAWINGS

The invention description below refers to the accompanying drawings, of which:

Fig. 1 is a schematic illustration of a direct oxidation fuel cell system including the cathode fluid controlling assembly of the present invention;

5 Fig. 2A is a schematic illustration of the cathode side of an air-breathing direct oxidation fuel cell system in accordance with the present invention;

Fig. 2B is an exploded schematic illustration of the cathode portion of Fig. 2A;

Fig. 2C is a schematic side section of the hinged frame embodiment of Fig. 2B in a closed position;

10 Fig. 2D is a schematic top plan view of one hinged frame in accordance with the present invention;

Fig. 3A is one component of a slidable shutter assembly of the present invention;

Fig. 3B is the second component of the slidable shutter assembly that has openings corresponding to those shown in Fig. 3A;

15 Fig. 4A is the slidable shutter assembly including the components of Figs. 3A and 3B illustrating the position in which the shutter assembly is almost fully closed;

Fig. 4B is a schematic illustration of the slidable shutter assembly in a substantially open position;

20 Fig. 5 is a schematic illustration of another embodiment of the invention in which a compressible element is employed;

Figs. 6A-6C illustrate further embodiments of the invention that employ expandable and compressible elements;

25 Figs. 7A and 7B are schematic illustrations of another aspect of the invention involving a sheet that when stretched has openings that allow for the flow oxygen there through;

Fig. 8A and 8B are schematic illustrations of a top and bottom plate, respectively, of another embodiment in the invention in which the top plate can be moved to allow a flexible element to fold providing an opening for oxygen to flow through;

30 Figs. 8C and 8D are schematic side sections of the embodiments of Figs. 8A and 8B; and

Fig. 9 is a schematic illustration of a direct oxidation fuel cell system that includes an actuator for actuating the fluid controlling assembly of the present invention;

## DETAILED DESCRIPTION OF AN ILLUSTRATIVE EMBODIMENT

Fig. 1 illustrates a fuel cell system 100, which includes a fuel cell 102 that has a membrane electrode assembly that includes a protonically conductive membrane 104. The protonically conductive membrane 104 has a catalyzed anode aspect 106 and a catalyzed cathode aspect 108. Diffusion layers are included such as anode diffusion layer 110 and cathode diffusion layer 112. Current collectors 114 and 118, (which may be comprised of an open, conductive structure), are used to collect and conduct electrons through a load 120. The fuel cell 102 is contained within a housing 130 which may include an oxygen-breathing face 132 that permits the flow of oxygen, which may be supplied from either ambient air or an oxygen source. The oxygen enters the cathode chamber of the fuel cell, which is generally designated with reference character 140, as a reactant on the cathode side.

In accordance with the present invention, an adjustable fluid-controlling assembly 150 is disposed in the cathode chamber 140. The adjustable fluid control assembly 150 of the present invention as illustrated in Fig. 1 (and as described in the other figures), may be constructed in a variety of alternative embodiments and may be deployed in several alternative locations relative to the other components of the fuel cell system. Further, it should be understood that such fuel cell system components may be fabricated and assembled in a variety of different manners. For example, a fuel cell may be supplied with liquid fuel, which may be presented to the anode aspect as a liquid. Alternatively, the fuel cell may include a methanol delivery film, MDF, which causes a phase change from a liquid to a vapor such that the anode aspect of the catalyzed membrane receives vaporous fuel. Furthermore, in some applications the entire fuel cell system 100 may be included within housing 130. In other instances, portions of the fuel cell system may be separate detachable components. A fuel cell system in any of these configurations, or

combinations thereof, such a stack of fuel cells are contemplated as being within the scope of the present invention.

The fluid-controlling assembly 150 of the present invention is used to regulate the amount of liquid water or water vapor that is maintained in the cathode chamber 140 to  
5 adjust the humidity near the PCM 104, in a manner hereinafter described. More specifically as the fuel cell 102 operates, water is created at the cathode aspect of the fuel cell 108 in the cathode reaction of Equation (2). It is desirable to control the amount of water contained within the cathode chamber 140 because to the extent the PCM is not well humidified, the cell can dry out which decreases performance or even halts operation  
10 of the fuel cell 102. However, another consideration is that if too much water builds up on the cathode side, the fuel cell can tend to flood, which also can lead to decreased performance. Accordingly, the fluid controlling assembly of the present invention 150 regulates water and oxygen within the fuel cell system 130 by allowing an increase in the rate at which water escapes from the cathode aspect of the fuel cell, as well by allowing  
15 increased oxygen access to the cathode aspect of the fuel cell.

More specifically, in accordance with the present invention the fluid controlling 150 regulates the amount of water that is kept near the membrane 104. The fluid controlling assembly 150 is actuated in this manner until the membrane of the fuel cell is properly hydrated. Thereafter, when a point is approached or reached in which there is  
20 too much water in the cathode chamber area, which could prevent sufficient oxygen from being introduced through the air breathing face 132, the assembly 150 is opened to allow more water vapor to escape by promoting evaporation and allowing more air (or oxygen) to enter the cell, and circulate through the cathode chamber of the fuel cell.

One aspect of the invention is illustrated in Figs. 2A through 2D. Fig. 2A shows a  
25 portion of a fuel cell system 200 on the cathode side, which is generally designated 202. The air-breathing face 204 of the fuel cell system 200 permits ambient air to enter the cathode chamber 202. In accordance with the present invention, an external face plate or frame 206 is fitted adjacent the air-breathing face 204. An exploded view of this embodiment of the invention is illustrated in Fig. 2B in which the cathode aspect 208 of  
30 the catalyzed membrane has a cathode diffusion layer 210. The fluid controlling

assembly 250 of the present invention is comprised of individual shutters 260, 262 and 264 that are rotatably attached about the hinges 270, 272 and 274 that are mounted to the frame 206. The shutters 260 -264 are shown in an open position in Fig. 2B. In Fig. 2C the shutters are shown in a closed position.

5           Oxygen is supplied directly or via ambient air, and enters the air-breathing aspect 280 of the direct oxidation fuel cell 200. The cathode shutters 260-264 are oriented perpendicular to the cathode aspect 208 of the fuel cell during fuel cell operation (open position). The hinges can be spring loaded to swing the shutters parallel to the cathode aspect of the fuel cell (closed position, Fig. 2C) during periods of stand-by or shut down  
10       operations, substantially closing the cathode chamber to air while retaining humidity within.

          One of the shutters 260 is illustrated in further detail in Fig. 2D. The panel 258 may be substantially comprised of material such as gas and liquid impermeable plastic films or sheets, or water pervaporative membranes that allow liquid exchange but would  
15       still retain specific humidity at the cathode. Alternatively, a gas permeable material that permits enough oxygen flux to continue operation, while still limiting water flux out, is also an alternative. A shutter made of this latter material could be left closed at substantially all modes of operation in accordance with this aspect of the invention. The material is stretched across a metal frame 256, which is a chemically inert material.

20           As noted, this embodiment of the invention (as well as the other embodiments) may be used as a means by which the fuel cell system can be controlled by limiting the introduction of oxygen to the cathode aspect of the fuel cell system. By limiting the availability of oxygen at the cathode aspect of the fuel cell, it is possible to limit the rate of the electricity generating reactions or cease them altogether, while still maintaining  
25       sufficient cathode humidification. Another embodiment of the invention is illustrated in detail with reference to Figs. 3A – 4B. More specifically, Fig. 3A illustrates a first component 302a of a slideable shutter assembly (Figs. 4A and 4B). The first component 302a, includes apertures such as the apertures 304a and 306a. The apertures 304a and 306a are shown as circular in Fig. 3A. However, the apertures may take any number of  
30       shapes, which may be advantageously employed depending upon the application of the



invention such as, for example, without limitation, rectangular shapes such as slots and serpentine shapes, provided that they properly maintain the desired water balance in the cathode chamber and allow for the flow of oxygen into the cathode chamber.

Fig. 3B illustrates the second component 302b, which includes apertures 304b and 306b, which have a corresponding or complementary shape and location with respect to the apertures of the first component 302a. The two components 302a and 302b are slideably adjusted with respect to one another, such that the alignment of the apertures 304a and 304b, for example, define openings to permit or restrict water and oxygen flow. The size of those openings can be controlled by the relative placement of the first component 302a with respect to second component 302b. Components 302a and 302b are fit together in such a fashion that when apertures on 304a and 304b are not aligned, they form a seal, regulating the rate at which water escapes from the cathode aspect of the fuel cell, and limiting the rate at which oxygen enters the cathode chamber of the fuel cell.

As illustrated in Fig. 4A, a combined shutter assembly 400 is illustrated. The first component 402a is in the position shown by the solid lines. The second component 402b (illustrated by dashed lines) has been adjusted in the direction of the arrow C. In the example of Fig. 4A, the apertures 404a and 406a are located with respect to the apertures illustrated by the dashed lines 404b and 406b in such a manner that the shutter assembly 400 is substantially closed. In other words, only a very small opening is left, as indicated by the letter x, allowing very little of the water present in the cathode chamber to escape from the fuel cell system, and physically limiting the access of oxygen to the cathode aspect of the fuel cell.

By comparison, Fig. 4B illustrates the substantially open shutter assembly 400. The first component 402a is shown by the solid lines and the second component 402b is shown by the dashed lines. In this position, the apertures 404a and 406a are almost exactly lined up with the apertures shown by dashed lines, 404b and 406b. This allows maximum water escape and oxygen flow through the corresponding openings (“y”) such as during fuel cell operations, perhaps in times in which cathode flooding is a possibility. Intermediate settings (not shown) could also be employed to control the flux of water from the fuel cell to the ambient and the rate at which oxygen may pass into the cathode



chamber of the fuel cell to a desired rate, based on the environmental and/or operating conditions.

In accordance with this embodiment of the invention, the entire shutter assembly 400 can be located within the fuel cell such as illustrated in Fig. 1 as the component 150.

5 In accordance with yet a further aspect of the invention, one of the shutters, such as the first component 402a could be located within the fuel cell 100 and the other shutter 402b could be located on the outside of fuel cell over the air-breathing face of the fuel cell, for example. It should be appreciated that the invention is readily adaptable to variations in the location of the individual components of the cathode fluid controlling assembly.

10 The actuation of the shutter assemblies, illustrated in Figs. 2A – 2D and that illustrated in Figs. 4A and 4B can be performed by a control system, such as the control system 408 (Fig. 4A), which includes a first means 409 for acting upon the shutter component 402a, and/or a second means 410 for acting upon the second component 402b. One or both means 409, 410 may be provided in a specific application of the  
15 invention. The control system 408 may include, for example, mechanical means, such as a wire formed from a shape memory alloy (SMA) such as a nickel-titanium (Nitinol) alloy, which will pull or push one or both of the two components 402a, 402b, relative to one another. Alternatively, a temperature sensitive bi-metal spring can act upon one or the other or both components 402a, 402b to adjust the relative positions of the two  
20 components. Temperature-controlled systems may, in turn, include a lever or spring, as noted in the control system 408. The shutter components 402a and 402b could also be physically moved manually relative to one another to achieve the desired fuel delivery control. These actuation mechanisms are equally applicable to the embodiment illustrated in Figs. 2A – 2D.

25 The movement of the shutter assembly components in Figs. 2A – 2D or those of Figs. 4A and 4B, may be controlled by servos acting upon one or both of the components and/or a motor could pull or push one of the components relative to the other. In addition, a gear and lever assembly could also be employed to adjust the location of the components.

The components of Figs. 3A – 4B may be comprised of a polymer such as DELRIN®, a registered trademark of E.I. DuPont de Nemours and Company, or a metal such as stainless steel, or any other suitable material that does not react substantially with the products and reactants of the reactions that occur in the fuel cell system.

5           Another embodiment of the invention is illustrated in Fig. 5. In Fig. 5, a cathode fluid controlling assembly 500 is shown in side view. The fuel cell includes PCM 503 that has a cathode aspect 504. The cathode fluid controlling assembly includes a water control element 525 that is a porous, compressible material. When the material of element 525 is under compression, its tortuosity increases such that less water is  
10           permitted to flow away from the cathode aspect 504 of the MEA 503 over a given time. This also alters the rate at which oxygen may be introduced to the cathode chamber of the fuel cell system. This embodiment may also be used to control the flow of oxygen into and out of the cathode chamber. The water control element 525 can be compressed by a variety of mechanisms, one of which is illustrated for example in Fig. 5. A compression  
15           device 527 that may in the illustrated embodiment be a backing plate fabricated of a rigid, but open construction that allows oxygen to flow through is towards the cathode aspect of the catalyzed membrane 503. But, when actuated, it acts to compress the flow control element 525. Pressure can be applied to compression device 527 by force-applying components 531a and 531b, which are anchored by a housing or mounting plate 539, thus  
20           causing a force to be applied to the compression device 527, which in turn acts to compress the flow control element 525. Consequently, flow control element 525 permits less fuel to flow through to the MEA 503.

          The force-applying components 531a, 531b may be Nitinol springs, such as those  
25           described earlier with respect to the actuation of other embodiments of the invention. Alternatively, the components 531a, 531b may be mechanical actuators, temperature sensitive devices, or flexible bladders that can be filled with anodically produced carbon dioxide that is routed to said bladders. The actuation means described with respect to the other embodiments of the invention, such as those that react to feedback from the fuel  
30           cell system may also be employed as the force-applying components 531a, 531b. Alternatively, the compression device 527 itself may be a flexible bladder or other

deformable material that may or may not need to be actuated externally, to act directly upon the control element 525. If compression device 527 is used as the force applying component, then force applying components 531a, 531b may be eliminated from the assembly. The components described may be used individually or in combination with  
5 other elements to perform the actuation of the flow control element 525.

Another aspect of the invention is described with reference to Figs. 6A – 6C. Fig. 6A illustrates a cathode fluid control assembly 600 that controls the flow of oxygen to the cathode aspect of MEA 623. Water is produced at the cathode aspect 624 of the MEA 623. The cathode fluid control assembly 600 includes a water control element 620 that is  
10 an expandable material. When the material of element 620 is actuated, it expands to maintain water near the MEA 603. The water control element 620 expands when it absorbs water, and it can be contracted to release the water and allow it to escape by a variety of actuation mechanisms, such as temperature changes, or a mechanical actuator that compresses the element 620.

Another specific embodiment of the invention is illustrated in Fig. 6B. A cathode fluid control assembly 630 includes a series of actuable, expandable components 631a, 631b and 631c. The expandable components 631a, 631b, 631c may be comprised of a material that expands at a selected level of hydration, thus increasing or decreasing the ability of water and/or oxygen to pass through said component, thus preventing  
20 dehydration of the membrane electrolyte. This expansion may occur in response to temperature changes, or mechanical actuation. A second series of components 635a, 635b, 635c and 635d, are, for example and not by way of limitation, interleaved between the expandable components 631a, etc. The second set of components 635a, etc., includes materials that deform when they are acted upon by an external force and might be used to  
25 compress the expandable components 631a-c, thus releasing the water from the component.

Another specific embodiment of the invention is illustrated in Fig. 6C. Fig. 6C illustrates a cathode fluid control assembly 640. The assembly 640 includes a porous material 642, which is preferably hydrophobic in nature, and which allows water and air  
30 to pass through it in a “normal” state. One or more expandable flexible bladders 644, are disposed within the porous material 642. Alternatively the porous material may be

applied to a flexible bladder 644, for ease of manufacturing. The flexible bladder 644 can be expanded by filling it with carbon dioxide routed from the anode aspect of the fuel cell. When the bladder 644 expands, the porous material 642 is deformed, causing water to be released from the pores in said porous material. This may occur by either expanding  
5 or contracting the bladder 644, depending on the configuration of the system. In this embodiment, when bladder 644 expands, the rate at which oxygen could be introduced to the cathode chamber, and the rate at which water can escape from the cathode chamber is limited. By doing so, the fuel cell operations can be slowed, or substantially stopped while maintaining membrane electrolyte hydration.

10 Yet a further embodiment of the invention is illustrated in Figs. 7A and 7B. Fig. 7A illustrates a sheet of an expandable film 702, which may be substantially water impermeable. However, the sheet 702 includes a plurality of perforations 704, 706 that are in the form of slits. When the sheet 702 is not deformed, the perforations 704, 706 are substantially closed as illustrated in Fig. 7A. However, when the elastic sheet 702 is  
15 stretched, the slit-like perforations 704, 706 open to provide apertures. When the sheet 702 is placed in its undeformed state next to the cathode aspect of the MEA in a fuel cell, it will maintain water near the MEA such as for example when the fuel cell is not in operation. But, when the material is stretched, so as to open the perforations, water is permitted to escape. The activation via stretching might be desirable in instances in  
20 which cathode flooding is a risk. Those skilled in the art will recognize that the sheet may be comprised of more than one material (not shown). These material may, but need not be, bonded together. In an embodiment where more than one material is used, it is possible that at least one of said materials will not be perforated, in order to more precisely control the rate at which water can escape from the cathode chamber and/or the  
25 rate at which oxygen can access the cathode chamber.

Another embodiment of the invention is illustrated in Figs. 8A through 8D. Fig. 8A illustrates a top assembly 802, which has several rods 810, 812, 814 and 816. Fig. 8B illustrates a bottom assembly 804, which has several rods 830, 832, 834 and 836. Flexible elements 822, 824, 826 and 828, which are impermeable to water, are attached to  
30 one rod on the top assembly 802 and one rod on the bottom assembly 804. When the top plate is placed over the bottom plate, the rods are aligned as shown in Fig. 8C,

stretching the flexible elements between the rods from the top assembly and bottom assembly, substantially maintaining water within the cathode chamber. When the top plate 802 is moved in the direction of the arrow D as shown in Fig. 8D, the flexible sections buckle and fold up to allow for substantially free flow of water and water vapor to escape out of the fuel cell system. This embodiment may allow for a more open construction, allowing for increased oxygen access, when opened, and increased escape of water vapor from the fuel cell system. Though shown as comprising multiple flexible elements, the invention specifically includes a system where a single flexible element is employed to regulate rate at which water escapes from the fuel cell, and/or the rate at which oxygen may be introduced to the cathode aspect of the fuel cell system.

Similar to the control system 408 described with respect to the shutter assembly 400, there are many ways in which the variable actuation of the other embodiments illustrated herein can be achieved. With reference to Fig. 9, a fuel cell 900 has PCM 904 that has anode aspect 906 and cathode aspect 908. The fuel cell 900 also includes anode diffusion layer 910 and anode flow field plate 912. In addition, the cell 900 includes cathode diffusion layer 914. The cathode fluid control assembly 950 of the present invention is illustrated as being adjacent to the cathode diffusion layer 914. The assembly 950 is coupled with an actuator 960. The actuator 960 receives signals from a microprocessor 962. The microprocessor is programmed in a suitable manner to respond to an input from an associated sensor or meter 964 and will send a signal to actuate the cathode shutter or other cathode fluid control assembly 950 under appropriate circumstances. Typical measurements which can be used to trigger the actuation of the invention are cell voltage and/or current, internal resistance and temperature, though other typical characteristics may also be employed, or the actuator may be manually triggered.

There are many methods of such control, including, without limitation, fastening a wire or other attachment comprised of a shape memory alloy such as a nickel-titanium (Nitinol) alloy, to at least one of the components to allow the components to be adjusted based on temperature. More specifically, temperature sensitive control mechanisms can be used for either the component or the sensor 964 to automatically adjust the assembly 950 in a temperature controlled system. When the operating temperature of the fuel cell



reaches a certain level, a temperature sensitive bi-metal spring for example, or temperature sensitive material will react in such a manner that the shutter assembly will be correspondingly adjusted automatically due to the change in temperature. The controls can also be regulated by an actuator whose operation is triggered based on feedback from the fuel cell system or a signal from the application device. Such feedback includes, but is not limited to, feedback that is generated in response temperature of the fuel cell, fuel cell system, or a component thereof, or which is can vary due to the amount or location of water that is present in the fuel cell system generally, and the cathode chamber of the fuel cell specifically. As noted, these variable actuation means, and combinations thereof can be applied to each of the embodiments described herein.

It should be appreciated that the fluid controlling assembly of the present invention can be used to maintain hydration of a catalyzed membrane on the cathode side of a direct oxidation fuel cell. The devices of the present invention can be selected in accordance with the particular application with which they are used in order to prevent cell dry out during non operating conditions. The fluid controlling assembly of present invention can also be actuated in order to rehydrate a cell upon startup of the cell. In addition, the fluid controlling assembly of the present invention can be opened to an intermediate position to allow some water to escape to prevent cathode flooding while maintaining enough water to keep the membrane well hydrated. The assembly of the present may also have the ability to control oxygen flow in an otherwise passive fuel cell system to thereby hold operation in a particular desired point of efficiency as selected in a particular application in which the present invention is employed.

The foregoing description has been directed to specific embodiments of the invention. It will be apparent, however, that other variations and other modifications may be made to the described embodiments, with the attainment of some or all of the advantages of such. Therefore, it is the object of the appended claims to cover all such variations and modifications as come with in the true spirit and scope of the invention.

What is claimed is: